

WHAT IS CLAIMED IS:

1. A lens system comprising;

a plurality of lenses, a stop, and a diffractive surface,

5        said lens system moving the whole or part of the lens system during focusing and satisfying the following condition:

$$\beta \geq 0.5,$$

where  $\beta$  is a maximum photographic magnification.

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2. The lens system according to Claim 1, wherein part of the lens system moves during focusing, and said a plurality of lenses is arranged symmetric or substantially symmetric with respect to said stop.

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3. The lens system according to Claim 1, wherein said diffractive surface consists of a diffraction grating rotationally symmetric with respect to the optical axis,

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wherein when the phase  $\phi(h)$  of said diffraction grating is given by the following equation:

$$\phi(h) = 2\pi/\lambda*(C1*h^2 + C2*h^4 + C3*h^6 + \dots + Ci*h^{2i}),$$

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where  $\lambda$  is an arbitrary wavelength in the visible region,  $Ci$  aspheric phase coefficients, and  $h$  a height from the optical axis,

the following conditions are satisfied:

$$C1 < 0 \text{ and } C2 > 0.$$

4. The lens system according to Claim 1, which satisfies the following condition:

$$|\Delta S/f| > 1.0,$$

5 where  $\Delta S$  is a maximum moving distance of the whole of said lens system during focusing from an object at infinity to an object at a near distance, and  $f$  a focal length of the entire lens system.

10 5. A lens system comprising;  
a diffractive surface, and  
a first lens unit of a positive refracting power, a stop, and a second lens unit of a positive refracting power in the order (named) from the object side,  
15 said lens system moves the whole of the lens system during focusing and changes air spaces before and after said stop during focusing.

6. The lens system according to Claim 5, which satisfies the following condition:

20  $0.7 < |\Delta s_1/\Delta s_2| < 1.3,$

where  $\Delta s_1$  is a moving distance of said first lens unit during focusing and  $\Delta s_2$  a moving distance of said second lens unit during focusing.

25 7. The lens system according to Claim 5, which satisfies the following conditions:

$$0.7 < f_1/f < 1.3, \text{ and}$$

$$1.5 < f_2/f < 2.5,$$

where  $f_1$  is a focal length of said first lens unit,  $f_2$  a focal length of said second lens unit, and  $f$  a focal length of the entire lens system.

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8. The lens system according to Claim 5, wherein said diffractive surface consists of a diffraction grating rotationally symmetric with respect to the optical axis,

10 wherein when the phase  $\phi(h)$  of said diffraction grating is given by the following equation:

$$\phi(h) = 2\pi/\lambda \cdot (C_1 \cdot h^2 + C_2 \cdot h^4 + C_3 \cdot h^6 + \dots + C_i \cdot h^{2i}),$$

where  $\lambda$  is an arbitrary wavelength in the visible region,  $C_i$  aspheric phase coefficients, and  $h$  a height  
15 from the optical axis,

the following conditions are satisfied:

$$C_1 < 0 \text{ and } C_2 > 0.$$

9. The lens system according to Claim 5, which  
20 satisfies the following condition:

$$|\Delta s_1/f| > 1.0,$$

where  $\Delta s_1$  is a maximum moving length of said first lens unit during focusing from an object at infinity to an object at a near distance, and  $f$  a focal length of  
25 the entire lens system.

10. A lens system comprising;

a diffractive surface, and

a first lens unit of a positive refracting power,  
a second lens unit of a positive refracting power, and  
a lens unit of a negative refracting power closest to  
5 an image, in the order (named) from the object side,  
wherein during focusing from an object at infinity  
to an object at a near distance said first lens unit  
and said second lens unit move toward the object side  
and an air space increases on the said object side from  
10 said lens unit of the negative refracting power.

11. The lens system according to Claim 10, which  
satisfies the following condition:

$$0.7 < |\Delta s1/\Delta s2| < 1.3,$$

15 where  $\Delta s1$  is a moving distance of said first lens  
unit during focusing and  $\Delta s2$  a moving distance of said  
second lens unit during focusing.

12. The lens system according to Claim 10, which  
20 satisfies the following conditions:

$$0.6 < f1/f < 1.1,$$

$$1.5 < f2/f < 3.5, \text{ and}$$

$$-6.0 < fR/f < -2.0,$$

where  $f1$  is a focal length of said first lens  
25 unit,  $f2$  a focal length of said second lens unit,  $fR$  a  
focal length of said lens unit of the negative  
refracting power, and  $f$  a focal length of the entire

lens system.

13. The lens system according to Claim 10,  
wherein said diffractive surface consists of a  
5 diffraction grating rotationally symmetric with respect  
to the optical axis,

wherein when the phase  $\phi(h)$  of said diffraction  
grating is given by the following equation:

$$\phi(h) = 2\pi/\lambda \cdot (C_1 \cdot h^2 + C_2 \cdot h^4 + C_3 \cdot h^6 + \dots + C_i \cdot h^{2i}),$$

10 where  $\lambda$  is an arbitrary wavelength in the visible  
region,  $C_i$  aspheric phase coefficients, and  $h$  a height  
from the optical axis,

the following conditions are satisfied:

$$C_1 < 0 \text{ and } C_2 > 0.$$

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14. The lens system according to Claim 10,  
wherein said first lens unit or second lens unit  
comprises a diffractive surface.

20 15. The lens system according to Claim 10,  
wherein said first lens unit and second lens unit  
comprise their respective, diffractive surfaces.

25 16. The lens system according to Claim 10,  
wherein said lens unit of the negative refracting power  
is fixed during the focusing.

17. The lens system according to Claim 10, which satisfies the following condition:

$$|\Delta s_1/f| > 1.0,$$

where  $\Delta s_1$  is a moving distance of the first lens unit during said focusing and  $f$  a focal length of the entire lens system.

18. A lens system comprising;

a diffractive surface, and

10 a first lens unit of a positive refracting power and a second lens unit of a negative refracting power in the order (named) from the object side,

wherein during focusing from an object at infinity to an object at a near distance, said first lens unit  
15 moves toward said object side and a spacing increases between said first lens unit and said second lens unit.

19. The lens system according to Claim 18, which satisfies the following conditions:

20  $0.5 < f_1/f < 1.1$ , and

$$-2.5 < f_2/f < -1.5,$$

where  $f_1$  is a focal length of said first lens unit,  $f_2$  a focal length of said second lens unit, and  $f$  a focal length of the entire lens system.

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20. The lens system according to Claim 18, wherein said first lens unit comprises a diffractive

surface.

21. The lens system according to Claim 18,  
wherein said diffractive surface consists of a  
5 diffraction grating rotationally symmetric with respect  
to the optical axis,

wherein when the phase  $\phi(h)$  of said diffraction  
grating is given by the following equation:

$$\phi(h) = 2\pi/\lambda*(C1*h^2 + C2*h^4 + C3*h^6 + \dots + Ci*h^{2i}),$$

10 where  $\lambda$  is an arbitrary wavelength in the visible  
region,  $Ci$  aspheric phase coefficients, and  $h$  a height  
from the optical axis,

the following conditions are satisfied:

$$C1 < 0 \text{ and } C2 > 0.$$

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22. The lens system according to Claim 18,  
wherein said second lens unit is fixed during the  
focusing.

20 23. A lens system comprising;  
a diffractive surface, and  
a first lens unit of a positive refracting power  
and a second lens unit of a positive refracting power  
in the order (named) from the object side,  
25 wherein during focusing from an object at infinity  
to an object at a near distance, said first lens unit  
moves toward the object side.

24. The lens system according to Claim 23, which satisfies the following conditions:

$$0.7 < f_1/f < 1.3, \text{ and}$$

$$f_2/f > 10,$$

5        where  $f_1$  is a focal length of said first lens unit,  $f_2$  a focal length of said second lens unit, and  $f$  a focal length of the entire lens system.

25. The lens system according to Claim 23,  
10        wherein said first lens unit comprises said diffractive surface.

26. The lens system according to Claim 23,  
15        wherein said diffractive surface consists of a diffraction grating rotationally symmetric with respect to the optical axis,

          wherein when the phase  $\phi(h)$  of said diffraction grating is given by the following equation:

$$\phi(h) = 2\pi/\lambda \cdot (C_1 \cdot h^2 + C_2 \cdot h^4 + C_3 \cdot h^6 + \dots + C_i \cdot h^{2i}),$$

20        where  $\lambda$  is an arbitrary wavelength in the visible region,  $C_i$  aspheric phase coefficients, and  $h$  a height from the optical axis,

          the following conditions are satisfied:

$$C_1 < 0 \text{ and } C_2 > 0.$$

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27. The lens system according to Claim 23,  
          wherein said second lens unit is fixed during the



focusing.

28. A lens system comprising;

a diffractive surface, and

5 a first lens unit of a positive refracting power,  
a second lens unit of a negative refracting power, and  
a third lens unit of a positive refracting power in the  
order (named) from the object side,

wherein during focusing from an object at infinity  
10 to an object at a near distance, said first lens unit  
is fixed, said second lens unit moves toward an image  
side, and said third lens unit moves toward the object  
side.

15 29. The lens system according to Claim 28, which  
satisfies the following condition:

$$0.50 < \Delta s_2 / |\Delta s_3| < 1.50,$$

where  $\Delta s_2$  is a moving distance of said second lens  
unit during the focusing and  $\Delta s_3$  a moving distance of  
20 said third lens unit during the focusing.

30. The lens system according to Claim 28, which  
satisfies the following conditions:

$$0.40 < f_1/f < 0.65,$$

25  $-0.50 < f_2/f < -0.25$ , and

$$0.40 < f_3/f < 1.10,$$

where  $f_1$  is a focal length of said first lens

unit,  $f_2$  a focal length of said second lens unit,  $f_3$  a focal length of said third lens unit, and  $f$  a focal length of the entire lens system.

5           31. The lens system according to Claim 28, wherein said diffractive surface consists of a diffraction grating rotationally symmetric with respect to the optical axis,

              wherein when the phase  $\phi(h)$  of said diffraction  
10       grating is given by the following equation:

$$\phi(h) = 2\pi/\lambda \cdot (C_1 \cdot h^2 + C_2 \cdot h^4 + C_3 \cdot h^6 + \dots + C_i \cdot h^{2i}),$$

              where  $\lambda$  is an arbitrary wavelength in the visible region,  $C_i$  aspheric phase coefficients, and  $h$  a height from the optical axis,

15       the following conditions are satisfied:

$$C_1 < 0 \text{ and } C_2 > 0.$$

              32. The lens system according to Claim 28, wherein said first lens unit comprises a positive lens  
20       closest to the object.

              33. The lens system according to Claim 28, wherein a stop is placed between said second lens unit and said third lens unit and said stop is fixed during  
25       the focusing.

              34. The lens system according to Claim 28, which

comprises a flare cut stop in the optical path.

35. The lens system according to Claim 28,  
wherein said second lens unit and said third lens unit  
5 both comprise their respective cemented lenses.

36. A lens system comprising;  
a diffractive surface, and  
a first lens unit of a positive refracting power,  
10 a second lens unit of a negative refracting power, a  
third lens unit of a positive refracting power, and a  
fourth lens unit of a negative refracting power in the  
order (named) from the object side,  
wherein during focusing from an object at infinity  
15 to an object at a near distance, the first lens unit is  
fixed, said second lens unit moves toward an image  
side, and said third lens unit moves toward the object  
side.

20 37. The lens system according to Claim 36, which  
satisfies the following condition:

$$0.50 < \Delta s_2 / |\Delta s_3| < 1.50,$$

where  $\Delta s_2$  is a moving distance of said second lens  
unit during the focusing and  $\Delta s_3$  a moving distance of  
25 said third lens unit during the focusing.

38. The lens system according to Claim 36, which

satisfies the following conditions:

$$0.40 < f_1/f < 0.70,$$

$$-0.45 < f_2/f < -0.25,$$

$$0.25 < f_3/f < 0.55, \text{ and}$$

5       $-1.0 < f_4/f < -0.4,$

where  $f_1$  is a focal length of said first lens unit,  $f_2$  a focal length of said second lens unit,  $f_3$  a focal length of said third lens unit,  $f_4$  a focal length of said fourth lens unit, and  $f$  a focal length of the entire lens system.

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39. The lens system according to Claim 36, wherein said first lens unit comprises a positive lens closest to the object.

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40. The lens system according to Claim 36, wherein a stop is placed between said second lens unit and said third lens unit and said stop is fixed during the focusing.

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41. The lens system according to Claim 36, which comprises a flare cut stop in the optical path.

42. The lens system according to Claim 36, wherein said second lens unit and said third lens unit both comprise their respective cemented lenses.

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43. The lens system according to Claim 36,  
wherein said diffractive surface consists of a  
diffraction grating rotationally symmetric with respect  
to the optical axis,

5            wherein when the phase  $\phi(h)$  of said diffraction  
grating is given by the following equation:

$$\phi(h) = 2\pi/\lambda*(C1*h^2 + C2*h^4 + C3*h^6 + \dots + Ci*h^{2i}),$$

             where  $\lambda$  is an arbitrary wavelength in the visible  
region,  $Ci$  aspheric phase coefficients, and  $h$  a height  
10          from the optical axis,

             the following conditions are satisfied:

$$C1 < 0 \text{ and } C2 > 0.$$

             44. A lens system comprising;  
15          a diffractive surface, and  
             a first lens unit of a positive refracting power,  
a second lens unit of a negative refracting power, a  
third lens unit of a positive refracting power, and a  
fourth lens unit of a positive refracting power in the  
20          order (named) from the object side,

             wherein during focusing from an object at infinity  
to an object at a near distance, the first lens unit is  
fixed, said second lens unit moves toward an image  
side, and said third lens unit moves toward the object  
25          side.

45. The lens system according to Claim 44, which

satisfies the following condition:

$$0.50 < \Delta s_2 / |\Delta s_3| < 4.00,$$

where  $\Delta s_2$  is a moving distance of said second lens unit during the focusing and  $\Delta s_3$  a moving distance of said third lens unit during the focusing.

46. The lens system according to Claim 44, which satisfies the following conditions:

$$0.20 < f_1/f < 0.60,$$

$$-0.50 < f_2/f < -0.10,$$

$$0.50 < f_3/f < 1.50, \text{ and}$$

$$0.70 < f_4/f < 1.80,$$

where  $f_1$  is a focal length of said first lens unit,  $f_2$  a focal length of said second lens unit,  $f_3$  a focal length of said third lens unit,  $f_4$  a focal length of said fourth lens unit, and  $f$  a focal length of the entire lens system.

47. The lens system according to Claim 44, wherein said diffractive surface consists of a diffraction grating rotationally symmetric with respect to the optical axis,

wherein when the phase  $\phi(h)$  of said diffraction grating is given by the following equation:

$$\phi(h) = 2\pi/\lambda * (C_1 * h^2 + C_2 * h^4 + C_3 * h^6 + \dots + C_i * h^{2i}),$$

where  $\lambda$  is an arbitrary wavelength in the visible region,  $C_i$  aspheric phase coefficients, and  $h$  a height

from the optical axis,

the following conditions are satisfied:

$C1 < 0$  and  $C2 > 0$ .

5           48. The lens system according to Claim 44,  
wherein during the focusing, said fourth lens unit is  
fixed relative to the image plane.

10           49. The lens system according to Claim 44, which  
comprises a stop in the optical path, wherein said stop  
is fixed during the focusing.

15           50. The lens system according to Claim 44, which  
comprises a flare cut stop in the optical path.

20           51. An optical device comprising;  
the lens system of Claim 1, and  
a housing which holds said lens system.

25           52. An optical device comprising;  
the lens system of Claim 5, and  
a housing which holds said lens system.

            53. An optical device comprising;  
the lens system of Claim 10, and  
a housing which holds said lens system.

54. An optical device comprising;  
the lens system of Claim 18, and  
a housing which holds said lens system.

5 55. An optical device comprising;  
the lens system of Claim 23, and  
a housing which holds said lens system.

10 56. An optical device comprising;  
the lens system of Claim 28, and  
a housing which holds said lens system.

15 57. An optical device comprising;  
the lens system of Claim 36, and  
a housing which holds said lens system.

58. An optical device comprising;  
the lens system of Claim 44, and  
a housing which holds said lens system.